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The Extended Lateral Supraorbital Approach and Extradural Anterior Clinoidectomy Through a Frontopterio-Orbital Window: Technical Note and Pilot Surgical Series

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■ BACKGROUND: **Lateral approaches to treat anterior cranial fossa lesions have evolved since the first frontotemporal approach described by Dandy in 1918. We describe a less invasive approach to perform extradural anterior clinoidectomy through a lateral supraorbital (LSO) approach for anterior circulation aneurysms and anterolateral skull base lesions.**

■ METHODS: **The extended LSO approach involves performing a standard lateral supraorbital craniotomy followed by drilling of the sphenoid wing and lateral wall of the orbit through the frontal bony opening of the LSO approach, without any temporal extension of the craniotomy. This creates a frontopterio-orbital window exposing the periorbita; superior, medial, and anterior aspect of the temporal dura mater; and superior orbital fissure. After unroofing the superior orbital fissure, the meningo-orbital fold is cut, and the temporal dura mater is peeled from the lateral wall of the cavernous sinus to expose the anterior clinoid process allowing a standard opening of the optic canal and anterior clinoidectomy.**

■ RESULTS: **The extended LSO approach and extradural anterior clinoidectomy allowed access to 4 sphenoid wing/anterior clinoidal meningiomas, 5 anterior circulation aneurysms, 2 temporomesial lesions, and 1 orbital/cavernous sinus abscess. Postoperatively, 2 patients had transient hemiparesis, 2 patients had transient third nerve palsy, and 1 patient had minimal visual field deterioration. All patients had a modified Rankin Scale score ≤1 at 8-week follow-up.**

■ CONCLUSION: **The extended LSO approach opens a new route (frontopterio-orbital window) to perform extradural anterior clinoidectomy safely and increases surgical exposure, angles, and operability of a less invasive keyhole craniotomy (LSO approach) to treat anterior cranial fossa lesions.**

INTRODUCTION

The lateral supraorbital (LSO) approach emerged as a less invasive and faster modification of the pterional approach to provide access to various vascular or tumoral lesions of the anterior skull base.[1-4] An expansion of this approach includes performing an intradural anterior clinoidectomy mainly for paraophthalmic aneurysms and anterior clinoidal meningiomas.[3] However, wide extradural access to the orbit and the cavernous sinus remains restricted, and this approach limits an intradural pretemporal route to the temporomesial structures and access to the posterior fossa lateral to the clinoid and supraclinoid carotid artery. The extradural anterior clinoidectomy (EAC) described and later refined by Dolenc[5,6] is a well-established technique to enhance surgical access to the skull base and to control critical neurovascular structures, such as the optic nerve, clinoidal internal carotid artery (ICA), and

Key words
- Anterior cranial fossa
- Extradural anterior clinoidectomy
- Intracranial aneurysm
- Lateral supraorbital approach
- Tumor

Abbreviations and Acronyms
AChA: Anterior choroidal artery
ACP: Anterior clinoid process
CN: Cranial nerve
CT: Computed tomography
EAC: Extradural anterior clinoidectomy
ICA: Internal carotid artery
LSO: Lateral supraorbital
MRI: Magnetic resonance imaging

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contents of the cavernous sinus.[5,7-13] It follows standardized steps and requires performing a pterional or an orbitozygomatic craniotomy.[5,14,15] In this study, we present a modification and extension of the standard LSO approach including a full removal of the sphenoid wing, opening of lateral wall of the orbit, and an EAC. This extended approach opens a frontopterio-orbital window without any temporal extension of the craniotomy to improve access to ICA aneurysms and anterior skull base lesions, including lesions in the cavernous sinus and in the temporomesial region.

METHODS AND MATERIALS

This study was approved by the Research Ethics Board. We conducted a retrospective analysis of patients treated by the senior author (I.R.) through an extended LSO approach.

Study Cohort

From January 2012 to April 2016, we retrospectively identified 12 patients who underwent an extended LSO approach and EAC performed by the senior author (I.R.) for treatment of anterior circulation aneurysms and neoplastic or infectious lesions of the anterior skull base. The 12 patients included 9 women and 3 men with a median age at diagnosis of 56 years (range, 21—77 years). We categorized preoperative and postoperative neurologic status at discharge and at 8-week follow-up according to the modified Rankin scale, immediate morbidity, and surgical complications. **Table 1** summarizes patient characteristics.

Surgical Technique: Extended LSO Approach and EAC

After performing a standard LSO craniotomy (**Figure 1A**),[2] under the operating microscope, the dura mater is detached from the orbital roof and the sphenoid wing (**Figure 1B**). Then the orbital roof and the sphenoid wing are thinned off using a 5-mm diamond drill, exposing the superior, medial, and anterior temporal dura mater, superior orbital fissure, and meningo-orbital fold (**Figure 1C**). All the bone drilling is performed through the frontal bony opening of the regular LSO approach, without any temporal extension of the craniotomy. This additional bony resection increases the extradural exposure and develops a flat trajectory from the subfrontal region toward the anterior skull base, orbit, and temporal pole, thus opening a "frontopterio-orbital" window, exposing the periorbita and the superior, medial, and anterior aspects of the temporal lobe extradurally. The superior orbital fissure is then unroofed, and the meningo-orbital fold is cut allowing stripping off the temporal dura mater from the anterior clinoid process (ACP) and the lateral wall of the cavernous sinus (**Figure 1D**). Next, the ACP is resected extradurally following a standard technique.[6,13] First, the optic canal is identified extradurally and opened with a 2-mm diamond drill, followed by drilling off the ACP using 3-mm and 2-mm diamond drills, then the optic strut is detached, and the remaining ACP is removed.[6,13] The dura mater is opened in a longitudinal manner along the sylvian fissure towards the optic nerve sheath and the distal dural ring (**Figure 1E**). An additional curvilinear cut is performed under the frontal lobe, and then multiple tack-up sutures are placed over the craniotomy edges, allowing complete exposure of the anterior cranial fossa and the surrounding neurovascular structures (**Figure 1F**).

Video available at WORLDNEUROSURGERY.org

RESULTS

Table 1 shows the surgical procedure, results, and postoperative outcome. We performed an extended LSO approach with partial or total EAC according to the need of skull base exposure and mobilization of neurovascular structures.

Illustrative Cases

Case 1. A 25-year-old woman presented with sudden onset of occipital headaches. Computed tomography (CT) scan of the brain showed Fisher grade 1 subarachnoid hemorrhage, distributed in the gyri of the convexity and without blood in the basal cisterns (**Figure 2A**). CT angiography and digital subtraction angiography revealed an 8-mm saccular aneurysm in the transition zone of the left supraclinoid ICA, between the clinoidal segment and the ophthalmic segment, projecting ventrally and not involving the origin of the left ophthalmic artery (**Figure 2B** and **C**). After a multidisciplinary discussion, this aneurysm was not considered the source of the bleeding. However, owing to the sex and age of the patient and uncertainty about the source of bleeding, we offered microsurgical treatment of the aneurysm after the patient recovered from the acute subarachnoid hemorrhage. The patient underwent a left extended LSO approach and total EAC as described earlier. The left ICA, left optic nerve, and anterior choroidal artery (AChA) were identified. A small infundibulum was visualized at the origin of the AChA. Then the distal and proximal dural rings were opened to obtain proximal control of the clinoidal ICA and to expose the aneurysm dome (**Figure 2D**). This aneurysm dome had a very thin wall, but there were no signs of previous rupture. The aneurysm neck was exposed and clipped using a curved 5.2-mm clip, and a second curved miniclip was applied to secure a small neck remnant (**Figure 2E**). Indocyanine green videoangiography showed patency of the parent vessel and exclusion of the aneurysm. At discharge, the patient had a left cranial nerve (CN) III palsy, which completely resolved at the 8-week follow-up, and she returned to full-time employment. See **Video 1**.

Case 2. A 21-year-old woman presented with a 2-month history of visual disturbances related to a right homonymous hemianopia. Magnetic resonance imaging (MRI) of the brain showed a 4-cm intra-axial lesion with bright heterogeneous gadolinium enhancement in the left amygdala and hippocampus extending into the temporal horn of the left lateral ventricle and ambient and perimesencephalic cisterns and compressing the midbrain (**Figure 3A** and **B**). MRI flow voids revealed that the tumor encased the left AChA and left posterior cerebral artery (**Figure 3C**). The patient underwent a left extended LSO approach and partial EAC to allow mobilization of the neurovascular structures and to obtain a wide surgical view of the temporomesial structures through a transsylvian and pretemporal route (**Figure 3D**). An intraoperative biopsy sample showed a pilocytic astrocytoma grade I,

Table 1. Patient Characteristics, Clinical Presentation, Surgical Procedure, and Outcome

Case	Age (years)/ Sex	Presenting Symptom	Preoperative mRS Score	Diagnosis	Approach	EAC	Complications	Treatment	mRs Score at Discharge	mRs Score at 8-Week Follow-Up	Visual Acuity
1	44/F	Conjunctival injection, left side decreased vision	1	Left anterior clinoid/ optic canal meningioma	Left extended LSO approach	Complete	No	Simpson grade 4	1	1	Vision improved (reported, no preoperative examination available)
2	80/M	Seizure	1	Left sphenoid wing/ anterior clinoid meningioma	Left extended LSO approach	Complete (no postoperative CT)	Conjunctivitis	Simpson grade 2	1	1	Vision improved
3	79/F	Asymptomatic (MRI for research purposes) slight inferior visual field defect in right eye	0	Anterior clinoid meningioma	Right extended LSO approach	Partial	Transient postoperative cognitive impairment, inferior field defect in right eye	Simpson grade 4	3	1	Vision deteriorated
4	77/F	Diplopia, right side decreased visual acuity	2	Right orbital/optic/ cavernous sinus abscess	Right extended LSO approach	Complete	No	Abscess drainage	1	1	Improved vision
5	23/F	Headache and somnolence	3	Left mesiotemporal ruptured cavernoma	Left extended LSO approach	Partial	No	Hematoma evacuation and resection	1	1	Vision unchanged
6	68/F	Left side visual field defect	1	Left unruptured carotid-ophthalmic aneurysm	Left extended LSO approach	Complete	No	Clipping	1	0	Normal vision
7	60/F	Regrowth of previously coiled ACoA aneurysm	0	Previously coiled ACoA aneurysm and left superior hypophyseal aneurysm	Left extended LSO approach	Complete	No	Clipping	0	0	Normal vision
8	67/F	Diplopia, left eye ptosis	1	Left PCoA aneurysm and left ACoA aneurysm	Left extended LSO approach	Complete	Transient right hemiparesis, left CN III palsy	Clipping	3	1	Vision unchanged
9	33/M	Headaches, nausea, vomiting	2	Left sphenoid wing/ anterior clinoid meningioma	Left extended LSO approach	Partial	No	Simpson grade 4	0	0	Vision unchanged
10	21/F	Visual disturbances/left hemianopia	1	Left temporomesial intra-axial tumor (pilocytic astrocytoma)	Left extended LSO approach	Partial	Transient right hemiparesis	Subtotal resection	3	1	Vision unchanged

Continues

Table 1. Continued

Case	Age (years)/ Sex	Presenting Symptom	Preoperative mRS Score	Diagnosis	Approach	EAC	Complications	Treatment	mRs Score at Discharge	mRs Score at 8-Week Follow-Up	Visual Acuity
11	26/F	Incidental finding/ unrelated SAH	1	Left ophthalmic segment—carotid cave aneurysm	Left extended LSO approach	Complete	Transient left CN III palsy	Clipping	2	0	Normal vision
12	52/F	Incidental finding	0	Left PCoA aneurysm	Left extended LSO approach	Partial	No	Clipping	1	0	Normal vision

mRS, modified Rankin scale; EAC, extradural anterior clinoidectomy; F, female; LSO, lateral supraorbital; M, male; CT, computed tomography; MRI, magnetic resonance imaging; ACoA, anterior communicating artery; PCoA, posterior communicating artery; CN, cranial nerve; SAH, subarachnoid hemorrhage.

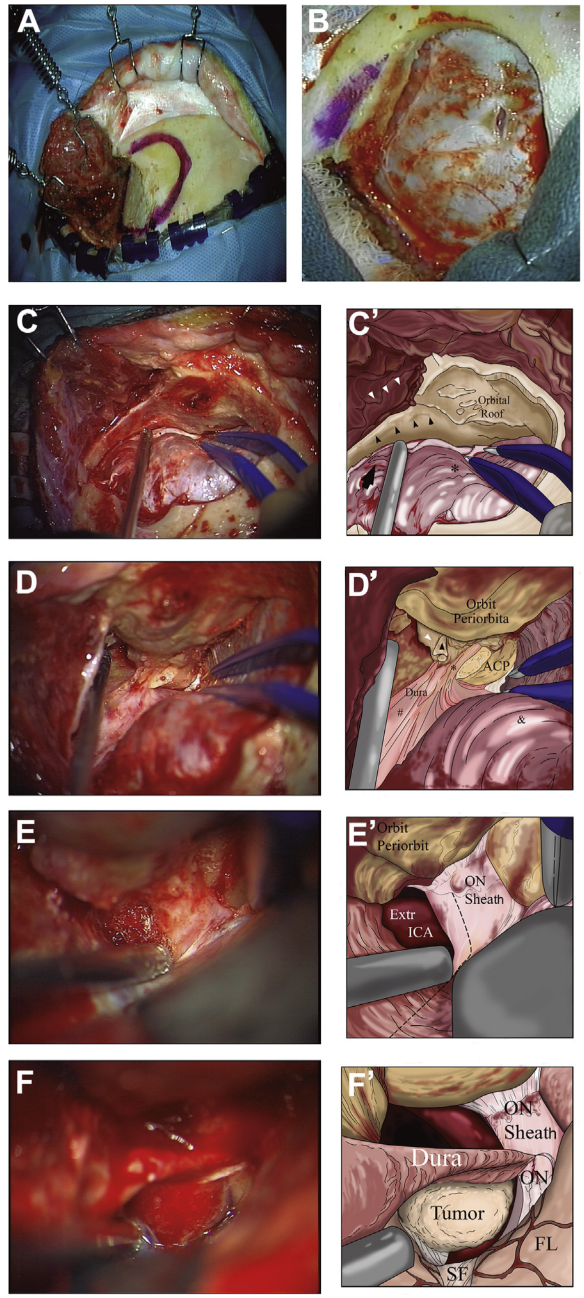

Figure 1. Intraoperative pictures and schematic drawings demonstrating the extended lateral supraorbital (LSO) approach and extradural clinoidectomy. (**A**) Planned craniotomy for a left classical LSO approach. (**B**) Craniotomy of a left LSO approach. (**C** and **C'**) Detachment of the left frontal dura mater from the lateral orbital wall. *White arrowheads*: superior portion of temporalis muscle, *black arrowheads*: sphenoid wing, *big black arrowhead*: sylvian fissure projection. *Frontal lobe extradurally. (**D** and **D'**) Left frontopterio-orbital window, demonstrating periorbita, meningo-orbital band, and unroofing of the superior orbital fissure. *white and black arrowheads*: superior orbital fissure. *Meningo-orbital band, [&]frontal Lobe extradurally, [#]temporal dura. (**E** and **E'**) Surgical and schematic views after performing a complete extradural clinoidectomy. (**F** and **F'**) Surgical and schematic views after dural opening and ipsilateral optic nerve exposure. ACP, anterior crinoid process; ON, optic nerve; Extra ICA, extradural internal carotid artery; FL, frontal lobe; SF, sylvian fissure.

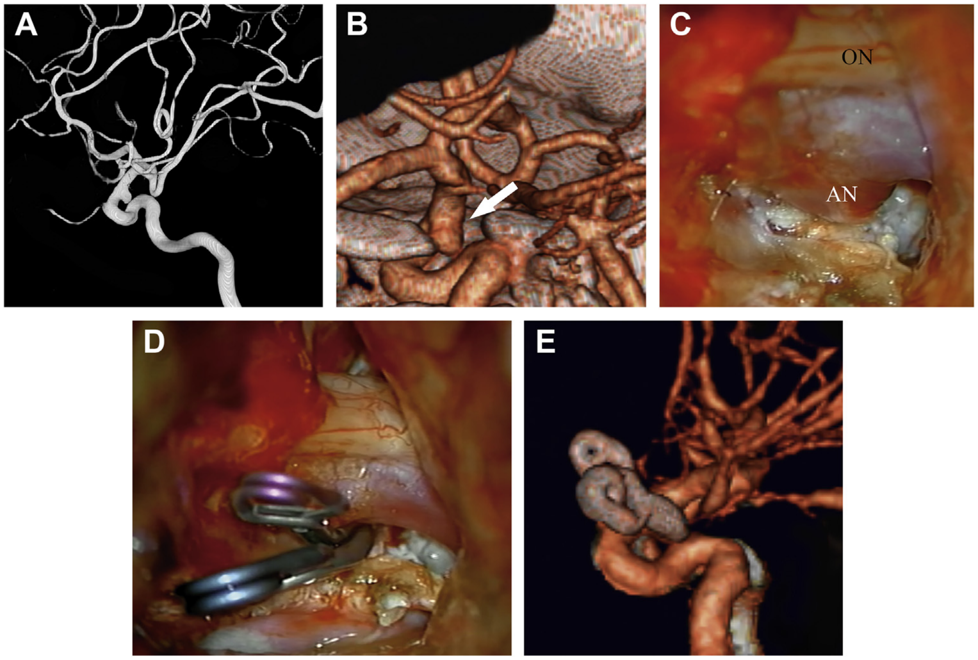

Figure 2. (**A**) Three-dimensional digital subtraction angiography demonstrating 8-mm left side clinoidal—ophthalmic segment aneurysm. (**B**) Three-dimensional computed tomography angiography demonstrating 8-mm left side clinoidal—ophthalmic segment aneurysm and relationship with left anterior clinoid process. *White arrow* showing paraophthalmic aneurysm. (**C**) Intraoperative picture after performing an extended lateral supraorbital approach, extradural clinoidectomy, and opening of the distal dural ring. (**D**) Clipping of the aneurysm. (**E**) Postoperative 3-dimensional computed tomography angiography demonstrating complete clipping of the aneurysm and patency of the parent vessel. ON, optic nerve; AN, aneurysm.

prompting a maximally safe resection strategy. The lesion was approached through the left limen insulae as described by Ture et al.[16] and a transsylvian/pretemporal approach (**Figure 3E**), achieving a subtotal resection and successful decompression of the midbrain with preservation of the encased AChA and posterior cerebral artery (**Figure 3F**). Postoperatively, the patient experienced a right hemiparesis that progressively improved; 5 days later, she was discharged for rehabilitation and neuro-oncologic assessment. At 8-week follow-up, the patient was able to walk without assistance and her vision remained unchanged. See **Video 2**.

Case 3. A 33-year-old man presented with a 2-day history of headaches, left retro-ocular pain, and vomiting. CT and MRI demonstrated a left-sided medial sphenoid wing and anterior clinoidal meningioma (**Figure 4A—C**) measuring 4.5 cm in diameter and causing significant mass effect on the frontal and temporal lobes with perilesional edema. The patient underwent a left extended LSO approach, left sphenoid wing resection, and extradural optic nerve decompression with partial EAC to reduce the risk of optic nerve manipulation and devascularize the tumor extradurally. The dura mater was opened in a curvilinear fashion, and the meningioma was disconnected at the base (**Figure 4D**). We performed a near-total resection of the tumor (**Figure 4E**), as we left a small residual adherent to a large middle cerebral artery perforator encased by the tumor. The pathology report identified the tumor as a World Health Organization grade II meningioma. The patient was discharged home 1 week after surgery and underwent radiation therapy assessment. The patient did not experience any postoperative complications. At 8-week follow-up, he was completely asymptomatic. See **Video 3**.

Complications and Outcomes

Two (17%) patients experienced transient CN III palsy secondary to manipulation of CN III during microsurgical clipping and dissection of the dural attachments, and 2 (17%) patients experienced transient hemiparesis related to ischemia in the territory of the AChA. One patient had a minimal deterioration of a pre-existing quadrantanopia. All patients had a modified Rankin scale score ≤ 1 at 8-week follow-up.

DISCUSSION

General Considerations

Lateral approaches to lesions of the anterior cranial fossa have evolved since the first macrosurgical frontotemporal approach described by Dandy[17] in 1918 and achieved maturity with the microsurgical pterional approach described by Yasargil,[18,19] while maintaining the same, shortest, anterolateral route to the central skull base and anterior circulation. Key elements of the pterional approach, including resection of the sphenoid wing and

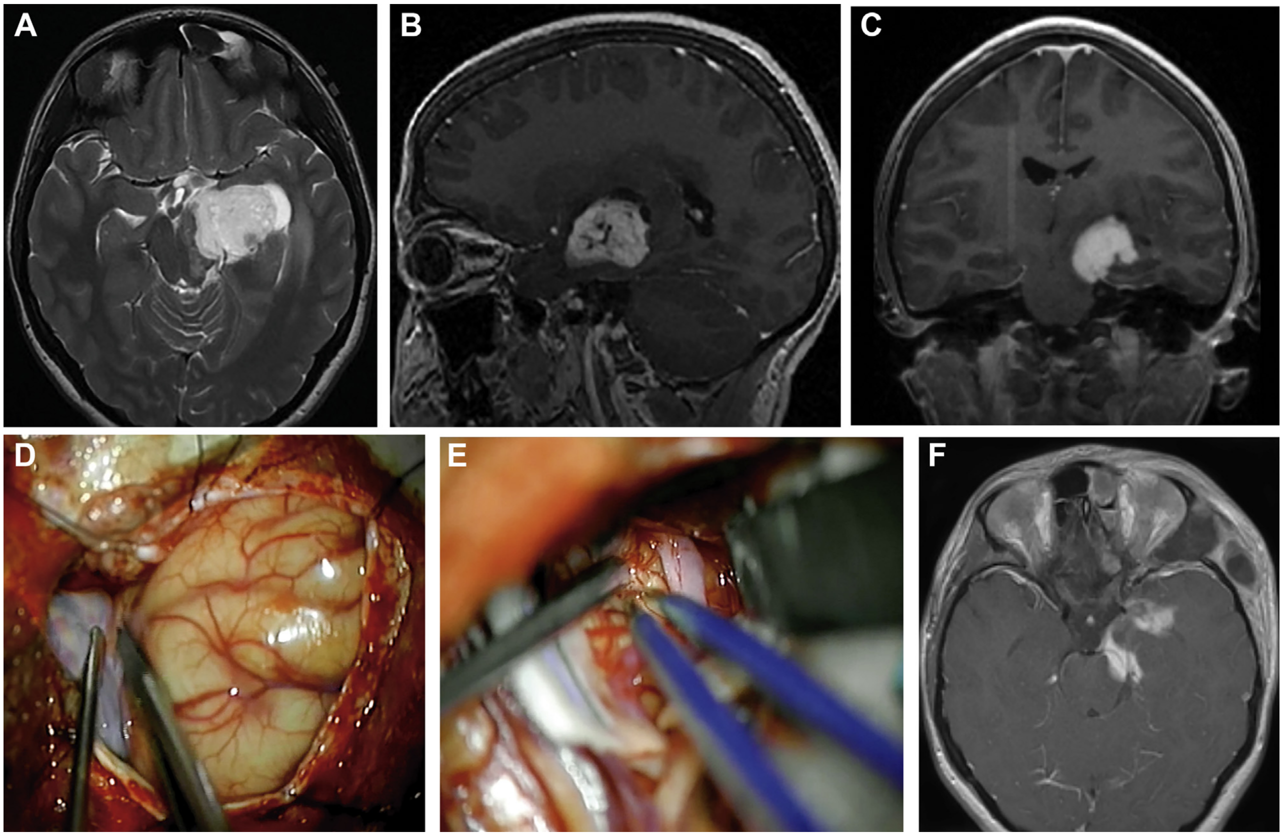

Figure 3. (**A**–**C**) Magnetic resonance imaging with gadolinium demonstrating an intra-axial lesion with bright heterogeneous enhancement in the left amygdala and hippocampus extending into the temporal horn of the left lateral ventricle and ambient and perimesencephalic cisterns and compressing the midbrain. Axial T2 (**A**), sagittal (**B**), and coronal (**C**) images. (**D** and **E**) Intraoperative pictures. (**D**) Initial surgical exposure. (**E**) Opening of the left limen insulae. (**F**) Postoperative magnetic resonance imaging with gadolinium.

microsurgical cisternal dissection principles, are techniques to reduce surgical invasiveness to the brain. Further evolution of variants of the pterional approach, either by its skull base extensions (orbitozygomatic osteotomy and anterior clinoidectomy) or by its reduction to keyhole bony openings, follows a similar logic of reduced invasiveness to the brain, soft tissues, or both.

The lateral supraorbital approach is a fast, simple, targeted yet versatile variant of the pterional craniotomy, which allows treatment of a wide variety of anterior circulation and skull base lesions, while decreasing skin and temporalis muscle trauma as well as unnecessary brain exposure. However, it does not allow extradural access to the central skull base, and its intradural exposure is limited by the sphenoid ridge and the ACP, hampering comfortable access to the temporal opercula in the sylvian fissure, temporomesial structures, and posterior fossa lateral to the supraclinoid carotid through a pretemporal route and along the tentorial ridge.

In this report, we present a technical modification of the LSO approach and its combination with a skull base technique (EAC) through the opening of a frontopterio-orbital window, allowing an enhanced access to structures that are not optimally exposed through a standard LSO approach. In essence, the extended LSO approach with EAC represents a combination of 2 previously established techniques, the LSO approach of Hernesniemi et al.[2] and the EAC of Dolenc[6] by adding their respective benefits in terms of breadth of exposure and limited invasiveness.

Surgical Cases

In our series, the extended LSO approach provided an adequate and comfortable surgical trajectory, exposure, and field of view similar to the standard pterional approach. A limitation of the previously described LSO approach is the anterior surgical trajectory compared with the lateral trajectory of the pterional approach.[20] However, this limitation of the trajectory is not present when performing the extended LSO approach, owing to the inside drilling of the sphenoid wing through the inner frontal region providing both surgical angles (lateral and anterior). Therefore, compared with the classical LSO approach, the extended LSO approach provides a wider range of surgical exposure, allowing complete exposure of the sylvian fissure and access to lesions involving the superior temporal gyrus,

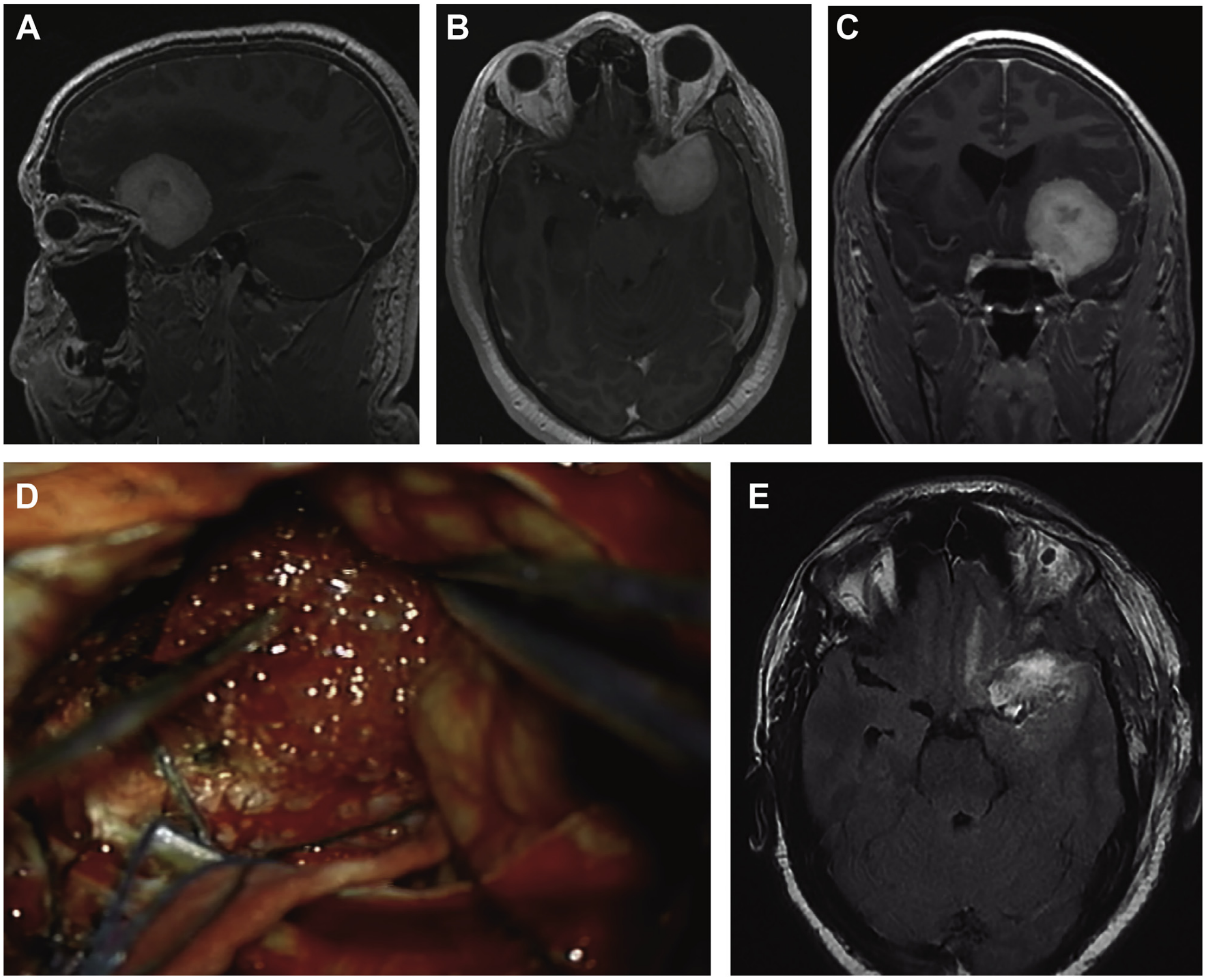

Figure 4. (**A**–**C**) Magnetic resonance imaging with gadolinium demonstrating a left side medial sphenoid wing and anterior clinoidal meningioma measuring 4.5 cm in diameter and causing significant mass effect on the frontal and temporal lobes with perilesional edema. Sagittal (**A**), axial (**B**), and coronal (**C**) images. (**D**) Intraoperative picture (subfrontal exposure of the tumor). (**E**) Postoperative magnetic resonance imaging with gadolinium.

mesial temporal region, cavernous sinus, interpeduncular region, and retrosellar area, as is illustrated by our surgical cases.

Among keyhole approaches, the minipterional craniotomy[21] is a good alternative to the LSO approach and has been used successfully for similar indications. In our practice, we have used the minipterional craniotomy approach for some middle cerebral artery aneurysms in which we think it has an advantage over the LSO approach, such as a long M1 segment or an aneurysm pointing inferiorly and embedded in the temporal opercula. Nevertheless, as the craniotomy is centered on the pterion with the superior temporal line as a superior limit, the frontal exposure is smaller than in the LSO approach. This smaller frontal exposure restricts the subfrontal route, the possibility of frontal lobe retraction (with retractors or dynamically with instruments), and the tangential angle along the frontolateral and frontobasal surface. Therefore, we believe that, similar to the LSO approach, the extended LSO approach provides a wider frontal exposure, while offering a pterional route and allowing an EAC by opening the frontopterio-orbital window.

Skull Base Drilling and Tailored EAC

Careful preoperative planning with 3-dimensional reconstruction images (CT angiography, MRI) and bony landmarks is essential when planning skull base drilling and anterior clinoidectomy. The degree of tailored EAC (partial or complete removal) depends on the amount of surgical exposure and mobilization required based on preoperative CT, 3-dimensional CT, 3-dimensional CT angiography, and MRI. Typically, access to a paraophthalmic aneurysm or anterior clinoid meningioma would require a complete

EAC, whereas a sphenoid wing meningioma or temporomesial mass would require a partial or minimal EAC.

The additional deep bone resection, removal of the orbital roof, and tailored anterior clinoidectomy open and enhance the deep surgical exposure in the same way that it would work in a traditional pterional approach. The advantages are the same as the advantages for the LSO approach over a full pterional craniotomy[2]—mainly a shorter frontotemporal skin incision or an eyebrow incision; minimal trauma to the temporalis muscle; less brain exposure; and an increased surgical operability, maneuverability, and surgical exposure.

CN III Palsy and EAC

Son et al.[22] reported a rate of transient CN III palsy of 27% (6 of 22 cases) in patients treated through a standard pterional approach and EAC. In our series, 17% (2 of 12 cases) experienced postoperative transient CN III palsy. The main reason for this transient palsy was posterior communicating artery aneurysm dome dissection and mobilization away from CN III in patient 8 and probably ACP drilling and removal in patient 11, who underwent surgery for a paraophthalmic aneurysm. This shows slightly better results while performing a minimally invasive technique and a skull base surgery tool as EAC.

CONCLUSIONS

The extended LSO approach opens a new route (frontopterio-orbital window) to perform an EAC safely and increases the surgical exposure, angles, and operability of a less invasive keyhole craniotomy (LSO approach) to treat anterior cranial fossa lesions.

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